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SPAWNING BIOMASS OF THE NORTHERN ANCHOVY IN 1987

by

Richard D. Methot and Nancy C. H. Lo

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Southwest Fisheries Center Admin. Rept. LJ 87-14

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Richard D. Methot and Nancy C. H. Lo

Southwest Fisheries Center
P.O. Box 271
La Jolla, CA 92038

ABSTRACT

The spawning biomass of the northern anchovy in 1987 is estimated to be 1.2 million mtons. The estimate was made by application of the Stock Synthesis (SS) Model to age composition data from the 1986 fishery at Ensenada, Mexico and to an egg production index derived from CalCOFI plankton samples. The SS Model has been revised to more carefully describe the seasonal nature of the fisheries, to incorporate a new egg production index based on the current CalCOFI sampling pattern, and to exploit environmental and biological indicators of the relative availability of young fish to the fisheries.

INTRODUCTION

Management of the northern anchovy fishery by the Pacific Fishery Management Council includes a harvest quota which varies annually as a function of the estimated spawning biomass (PFMC, 1983). The NMFS Southwest Fisheries Center (SWFC) is responsible for the annual spawning biomass estimate.

Since 1980, the SWFC has estimated the spawning biomass by the egg production method (EPM). This method uses plankton samples to measure the abundance of newly spawned eggs, and midwater trawl samples to collect adults and measure the rate at which mature adults are producing eggs (Lasker, 1986). Spawning biomass is, basically, the ratio of these two quantities. The method is accurate; coefficients of variation typically are 15-20% (Bindman, 1986).

The anchovy FMP recognized that it was unnecessary to apply the EPM every year and that it was important to calibrate other sources of stock assessment data to the EPM. This has become especially true with the decline of the U.S. anchovy reduction fishery and the need to devote resource assessment effort to other species. Methot (1986) developed the Stock Synthesis Model to integrate the EPM observations with other data: biomass indexes, age composition from U.S. and Mexican fisheries, age composition from CDF&G surveys, and environmental data. The model achieved four goals: by calibrating the EPM to historical types of data, a 35 yr time series of abundance was constructed; by including age composition data during the period of EPM observations, the spawning biomass estimates became more precise than

the original EPM observations; by including several realistic biological relationships, the SS Model is a tool for exploring the magnitude and consequences of these relationships; and by calibrating current data sources, current spawning biomass can be estimated without conducting an EPM survey.

Methot (1986) used the SS Model to estimate the spawning biomass in 1986 on the basis of Mexican fishery landings and age composition during 1985, and a CDF&G survey in February 1986 which produced an age composition estimate and a schooled biomass index (acoustic survey). The purpose of this report is to identify recent changes made to the SS Model, to describe a revision to the Historical Egg Production (HEP) index (Lo, 1985), and to document the spawning biomass estimate for 1987. Model revisions and the revised Historical Egg Production index reported here are preliminary and are not intended for any purpose other than estimation of the 1987 spawning biomass. A full revision of the HEP and SS Model awaits further analysis.

DATA REVISIONS

Modified Egg Production Index

Spawning biomass of northern index is measured most accurately by the Egg Production Method which was used during the period 1980-1985. This technique measures the abundance of newly spawned eggs and the rate at which mature adults are producing eggs. Estimates of the abundance of newly spawned eggs prior to 1980 were made by Lo (1985) using data from CalCOFI surveys. This index of historical egg production (HEP) included samples

from approximately San Francisco, CA to Pt. Baja, Baja California (30^{o}N) during January - April. The egg production values were estimated by fitting a mortality curve to the abundance of eggs and sized larvae.

Beginning in 1985 the CalCOFI survey pattern changed. The frequency of surveys was increased from near monthly cruises each triennium to quarterly cruises each annum, and the geographic extent was restricted to CalCOFI lines 76.7 (Pt. Buchon, CA) to 93.3 (Del Mar, CA). This change required a recalibration of the HEP index because the mean egg density in this restricted area is not expected to be the same as the mean density in the larger area. Since 1980, only samples collected during February - March were selected for this revised index because this is the time period during which subsequent data is expected to be collected.

The modified egg production index (MHEP) was derived from the egg mortality curve: $P_t = P_o \exp(-zt)$, where P_t is the abundance of some life stage (or size category) corrected for the duration of that stage and z is mortality rate. By rearranging the terms in the equation, one obtains $P_o = P_t \exp(zt)$, and an estimate of P_o can be computed if the egg mortality rate (z) and at least one age-specific egg production are known. Because of the reduced sample size in the modified survey area, estimates of z were taken from Lo (1985) and are based on the larger area previously sampled by CalCOFI. P_t's can be computed from egg and larval data from the modified survey area. We have for the historical data set two P_t's which are reasonably close in age to the age at spawning; one for the egg stage (P_{egg}) and the other

for the yolk-sac larvae (P_{ys}). The historical anchovy database provides only the standing stock of anchovy eggs, with no information on the egg stage distribution. To obtain an average egg production rate, we divided the standing stock by the average temperature-specific incubation time to obtain the egg production rate (P_{egg}) at the mid-age (t_{egg} = incubation time / 2). From the mortality curve fit to sized larvae (Lo 1985), we estimated the larval production rate at the age of yolk absorption (P_{ys}). Assuming that eggs and yolk-sac larvae suffer the same mortality, two initial egg production estimates were computed as follows:

$$P_{o\text{-}egg} = P_{egg} \exp(z\, t_{egg})$$

and

$$P_{o\text{-}ys} = P_{ys} \exp(z\, t_{ys}).$$

The MHEP egg production index is the average of the above two estimates:

$$MHEP = (P_{o\text{-}egg} + P_{o\text{-}ys})/2.$$

The variance of MHEP (Table 1) was computed as:

$$var(MHEP) = [var(P_{o\text{-}egg}) + var(P_{o\text{-}ys})] / 4.$$

The two variances at the right side of the equation were computed by the delta method (Lo 1985).

Fishery Data

Landings and age composition data from the U.S. and Mexican fisheries originally were summarized strictly on a quarterly basis. This summarization can distort the true nature of the fishery, e.g. availability of age 0 fish changes rapidly during the third quarter, and the fourth quarter Mexican fishery often

is active only during October. Recent access to monthly Mexican fishery data (J. Thomas Barnes, Living Marine Resources, unpubl. data) and the raw data file for U.S. age composition data enabled a more logical reassembly of the data.

Monthly landings, age composition, and weight at age were examined for sharp changes. On the basis of these changes, four periods were defined in each year. Each period contained one to five months, and January data often were combined into the fourth period of the previous year. Periods for the U.S. fishery were defined independently from the Mexican fishery. Within each period, monthly age composition and weight at age data were weighted by the total landings for that month before combining with other months in the period. The revised U.S. fishery landings and weight at age are in Table 2; revised Mexican fishery landings and weight at age are in Table 3; and revised age compositions are in Table 4.

In the SS Model, each period's landings and age composition are analyzed as if they came from a three month quarter. While this is not true, neither is it true that strict quarterly data are distributed evenly over the quarter. What the new "flexible period" summarization achieves is more consistency within each period.

Weight at Age Deviations

The original SS Model disclosed that the older age groups disappeared during the 1982-83 El Niño and reappeared in about 1985. The model attempted unsuccessfully to track this change in availability using Jan-Feb ocean temperature at San Diego as an

explanatory variable.

Examination of the monthly Mexican fishery data indicated that the disappearance of the older age groups was coincident with a decline in size at age of the younger age groups (Figure 1). This is an expected correlation because size at age and percentage old fish decreases in the south (Parrish, et al., 1985). The new version of the SS Model attempts to exploit this correlation to achieve a better fit to the age composition data. A time series of quarterly weight at age deviations was included in the model and the age-specific availability parameters were made functions of environmental deviations (see below) and weight at age deviations. The weight at age deviations were calculated as follows:

1. Calculate mean weight at age for each month.

2. For each month and each age, calculate the deviation in weight at age.

3. For each specified period, calculate the mean deviation for ages 1-3.

Mean weight at age and weight deviation was calculated separately for the U.S. fishery and for the Mexican fishery (Table 5). Seven quarters of simultaneous data occurred during 1978-4 through 1982-2. Unfortunately there was little range to the deviations during this period, so a test of the equivalence of the two types of deviations has little power. We assume that the two types of deviations are equivalent; simultaneous U.S. and Mexican weight at age deviations were averaged. A 2 quarter weighted average of the weight at age deviation was used in the

revised SS Model: the deviation for the current quarter was given a weight of 2.0 and the deviation in the previous quarter was given a weight of 1.0. Missing data were interpolated from adjacent values.

Environmental Data

The original SS Model used Jan-Feb temperature at the SIO pier as an indicator of the percentage of age 1 fish that were spawning, and as an indicator of the relative availability of young fish throughout the year. When used as an availability indicator, the value was a weighted average of the current year's temperature and temperature in the previous 3 Jan-Feb periods.

A new comprehensive compilation of monthly environmental data in southern California (Prager and MacCall, 1986) enables a more accurate description of the changes in the anchovy habitat. Two variables were selected to indicate anomalies in alongshore transport: temperature and sea level at the SIO pier. Prager and MacCall calculated monthly means and standard deviations for the period 1920-1983, then transformed the raw data to unit normal deviations. We calculated mean tri-monthly deviations for each data type beginning in December 1950. The resultant series are correlated ($r^2 = 0.45$), but since 1978 the sea level deviations have been larger than expected (Figure 2). Until this change in the relation between temperature and sea level is explained, we will use only temperature anomalies at the SIO pier as the environmental indicator. Two series were derived from the quarterly anomalies. One, ENVSHORT, used the current and previous quarter, just as the weight at age deviation. The other

series, ENVLONG, used the current and 15 previous quarters, using a linear weighting scheme (current quarter's weight = 16, lag -15 quarter's weight = 1) . ENVSHORT was detrended by subtracting ENVLONG from it.

Since 1978, the quarterly temperature deviations are related to the weight at age deviations (Figure 3). Warm water apparently shifts the stock north and causes a decline in size at age in the Mexican fishery. No relationship between these two indicators is apparent for the 1967-1977 period. Note that fish in the U.S. fishery were small during 1972-73 (Table 5) which was a minor El Niño; however the temperature and sea level anomalies at the SIO pier did not strongly indicate the EL Niño conditions.

MODEL REVISIONS

Temperature Effects on Percentage Mature

The percentage of age 1 fish that are sexually mature is a vital link between the age-structured number of fish in the population and the measured spawning biomass. Methot (in prep.) described a relation between the percentage mature at age 1 and the winter ocean temperature at the SIO pier; age 2 and older fish seemed to be at least 90% mature in all years. Although the age 1 relation was included in the SS Model (Methot, 1986), the low value of HEP in the cold (12.8^{o}C) winter of 1972 could not be closely matched by the model. This suggested that some older anchovy may not have been spawning in that year. The temperature-maturity relation was defined on the basis of the CDF&G

trawl database which did not include a survey in 1972. Preliminary examination of the biological database from the U.S. fishery indicates that only 50% of the age 2 fish were mature in 1972. This anomaly has been included in the revised SS Model.

Estimated Age-Specific Availability

Three types of parameters define age-specific availability for each type of age composition (US survey, US fishery, MX fishery). Survey age composition data from Mexican waters were included in the original SS Model but are deleted here because there are no samples of this type since 1984, and none of the 7 previous samples had sample sizes greater than 260 fish aged.

Ten parameters define MAXAGE, the age at which availability = 1.0. The first 3 parameters set the mean level for each type of age composition. Three parameters define ENVLONG, ENVSHORT, and WTDEV effects on both US age compositions. Three parameters define ENVLONG, ENVSHORT, and WTDEV effects on the Mexican fishery age composition. The tenth parameter defines a spring quarter effect for the US.

Similarly, ten parameters define AV-1, the rate at which availability declines for ages less than MAXAGE.

Six parameters define OLDAV, the rate at which availability declines for ages older than MAXAGE. Environment and WTDEV effects were included for only the Mexican fishery age composition.

Observed Age-Specific Availability

The SS Model defines fishing mortality on each age group as

the product of a time-specific fishing effort and an age-specific availability. As the original model projected the population's abundance from one quarter to the next, the removals from the population were based on the estimated fishing mortalities, not on the observed numbers of fish in the age composition samples from the fishery. Of course, these two alternatives are equivalent when the modeled age-specific fishing mortalities (hence estimated catch age composition) closely match the true mortalities (and observed catch age composition). When the modeled catch age composition did not closely match the observed catch age composition, it seems reasonable to adjust the fishing mortalities on the basis of the observed catch age composition. However, this adjustment is difficult because error in the age determination process is assumed to perturb the relation between the true fishing mortalities and the observed catch age composition. The following iterative procedure was used to approximate the observed age-specific availabilities in each quarter for which there was age composition data:

1. Calculate the estimated age-specific availability, AV_e, based on environmental and weight at age data, time of year and type of fishery.

2. For each age, calculate the geometric mean between AV_e and the previous availability approximation, AV_o. Define this as the trial availability, AV_t. Standardize AV_t so that the age with availability = 1.0 remains unchanged.

3. Use AV_t to calculate fishing mortality, survivorship, and mean abundance during the quarter. In the original SS Model, AV_e

was used for this purpose.

4. Use mean abundance, estimated availability (AV_e), and ageing error to calculate the estimated catch age composition. Use this age composition for goodness of fit comparison to the observed age composition, OBSERV. This is the same procedure as the original model.

5. Use mean abundance, trial availability (AV_t), and ageing error to calculate the approximated catch age composition, APPROX.

6. Calculate a new availability approximation for each age, except the age at which availability = 1.0:

$$AV_o(\text{new}) = AV_o(\text{old}) * \frac{\text{OBSERV} - \text{OBSERV}*\text{APPROX}}{\text{APPROX} - \text{OBSERV}*\text{APPROX}}$$

7. Iterate step 6 three times and retain AV_o for the next call to the evaluation routine.

DATA FOR 1987 SPAWNING BIOMASS ESTIMATE

The reduction fishery based in Ensenada, Baja California, Mexico dominates the total fishery with landings ranging from from 79,000 to 259,000 mtons during 1980 - 1985. Up to date landings data are needed for calculation of survivorship from the previous year's biomass estimate. In addition, age composition information from the autumn fishery indicates the level of recruitment, hence additions to the spawning biomass since the previous year's estimate. Monthly landings, age composition, and weight at age data for 1986 (Table 6) were obtained through a

contract with Living Marine Resources, Fisheries Research, Inc. (7169 Construction Court, San Diego, CA 92121; Contract #43ABNF7-1348).

The total landings at Ensenada during 1986 were 96,417 mtons, which is 48% of the 200,000 mton optimum yield. The 1985 year class, which seemed strong during autumn 1985, continued to dominate the landings during late spring 1986. During August 1986, the incoming 1986 year class began to dominate the fishery. Size at age was larger than normal during much of 1986 (Table 6); this phenomenon suggests a southward shift of the population following the EL Niño of 1982-83.

Plankton samples collected on the March 2 - 17, 1987 CalCOFI cruise provide the basis for an estimate of the population's spawning biomass. Eggs and sized larvae from the bongo plankton net and staged eggs from CalCOFI vertical egg tows were used to estimate a value similar to the Historical Egg Production index (Lo, 1985) but on a restricted geographic basis (see modified HEP above). Analysis of staged eggs and yolksac larvae indicates daily egg mortality of $-0.338\ day^{-1}$ in 1986 and -0.186 in 1987. The large estimated egg production rates (MHEP) in 1986 and 1987 (Table 1) suggest that spawning biomass has increased 242% since the 1980-85 period of EPM observations.

Environmental Data

Following the California El Niño of 1982-83, ocean temperatures cooled in southern California (Table 5) but typically remained above the long-term monthly mean. During Jan-Feb 1987 the temperature at the SIO pier was $15.0^{o}C$. At this temperature,

the temperature-maturity relation estimates that 96% of the age 1 fish are sexually mature and 65% of them are actively spawning, hence contributing to the MHEP index. Higher temperatures tend to shift the population towards the north, causing an decrease in size at age in the Ensenada fishery. However, weight at age in the Mexican fishery during 1985 and 1986 was, typically, 1-2 g greater than normal (Table 5). Weight at age during 1986 seems greater than expected based on the ocean temperature (Figure 3).

Methot (1986) hypothesized that predation by Pacific mackerel increases natural mortality of northern anchovy. Pacific mackerel biomass was estimated to be in the range 245,000 - 900,000 mtons on July 1, 1986, and projected to be 378,000 - 1,000,000 mtons on July 1, 1987 (Karen Wooster, CDF&G, unpubl. report). A value of 500,000 mtons was used in the model for the years 1986 and 1987. At this level of mackerel biomass, natural mortality of anchovy increases from the nominal level of 0.6 to a level of 0.8 yr^{-1}.

RESULTS

1987 Spawning Biomass

The spawning biomass in February 1987 is estimated to be 1,212,000 mtons (Table 7). This value is more than double the 1985 spawning biomass which was measured by the EPM to be 521,000 mtons (Figure 4). The large increase occurs because the observed increase in the modified HEP index (Figure 5) is consistent with the strong showing of the 1985 and 1986 year classes in the Mexican fishery (Figure 6 a-h).

1986 Spawning Biomass

Last year the 1986 spawning biomass was estimated to be 745,000 mtons (Methot, 1986). We have revised that estimate to 764,000 mtons. This is a remarkably small change considering the model changes, an additional year of Mexican fishery age composition data, and inclusion of the modified HEP index.

Performance of the Modified Historical Egg Production Index

The MHEP observations deviated from expected with a lognormal standard error of 0.50. This is greater than the error for the EPM (0.17) and the original HEP (0.43), and similar to the error for the sonar biomass index (0.51). The largest MHEP deviation occurred in 1978 where the observed value was nearly 3 times the predicted.

Availability Patterns

The combined effect of the long-term and short-term environmental deviations and the weight at age deviations was as expected: young fish are relatively more available when the temperature is warm and the fish are small (Table 8). The contribution of individual parameters to this pattern is difficult to describe because of the obvious high covariance among the many parameters. Attempts to describe the "best" reduced parameter set should await transfer of the model to a faster computer. Current run times are 2-6 hours without calculation of the mixed-partial derivatives.

Alternative Models

Although selection of the "best" availability model is not attempted here, two alternative models should be discussed. The first did not use long-term temperature deviations and constrained the sign of the temperature and weight at age parameters that it did use. Temperature effect parameters were constrained to increase the relative availability of young fish, and weight at age parameters were constrained to decrease the availability of young fish. All types of abundance and age composition data were fit more poorly by this model than by the full model described above. Additionally, the constrained model resulted in a smaller environmental effect on Mexican age composition availability; therefore the recent high percentages of young fish were interpreted as very large recruitments, resulting in 1987 biomass estimates near 1.7 M mtons.

The second alternative model was derived from the constrained model. Beginning in 1984, Mexican fishery availability was forced to be 1.0 beginning at age 0 in the fourth quarter. This forcing is contrary to the observed environmental indicators: temperature decreased and weight at age increased in 1985-86; historically, this pattern has indicated a decrease in availability of young fish. In the full model, age 0 fish were estimated to be 64% available in the fourth quarter of 1984, 49% available in the fourth quarter of 1985, and 25% available in the fourth quarter of 1986. The forced model reduced the estimated size of the 1986 yearclass to an average level and resulted in a 1987 spawning biomass estimate of 840,000 mtons.

Given the uncertainty in the post-El Niño availabilities to the Mexican fishery, current spawning biomass could be as small as 840,000 mtons or as large as 1.7 M mtons, but a value of about 1.2 M mtons seems most likely. This biomass level is similar to the level which occurred in 1974-75. Uncertainty in biomass levels ranging around 1 M mtons are not critical to current management, because the harvest quota is constant for biomass levels greater than 500,000 mtons.

NEW DIRECTIONS

1. The actual seasonal distribution of CalCOFI egg and larval surveys should be taken into account. In the original HEP, January - April cruises were assumed to be equivalent, or to be equally sampled. However, January typically has lower egg and larval abundance (MacCall and Prager, 1987) and lower spawn production by the adults. Since 1980, the frequency of January surveys has decreased (Table 1 in MacCall and Prager, 1987) so the expected value for the HEP index should have increased. A correction factor for uneven sample distribution was derived from the month weights in MacCall and Prager (Jan = 0.065, Feb = 0.238, Mar = 0.323, and Apr = 0.374) and from the monthly number of plankton tows in CalCOFI regions 7,8, and 9:

$$\text{FACTOR} = \frac{\text{sum}\ (\ \text{NTOW}_{\text{month}} \times \text{WEIGHT}_{\text{month}})}{\text{sum}\ (\text{NTOW}_{\text{month}}) \times \text{MEAN WEIGHT.}}$$

The FACTOR has a value greater than 1.0 when the month of January is undersampled, and less than 1.0 when January is oversampled. If the seasonal distribution of sampling has influenced the HEP

values, then positive deviations in HEP (relative to the SS model's expection) should be related to large values of the seasonal correction factor. However, this does not occur; the correlation coefficient is only 0.01 (Figure 7). Further work on the seasonal distribution of spawning and sampling should be pursued.

2. The environmental effects on availability are manifested because of north-south gradients in stock structure. The model could logically be revised to explicitly account for this geographic structure; e.g. rather than define availability relative to the entire stock, availability would be defined relative to the portion of the stock expected to be found in the region from which the samples were taken. Examination of the north-south distribution of larvae (Figure 8) suggests that north-south shifts in the total spawning population follows an environmental cue similar to that inferred from patterns in age composition.

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Table 1. EPM is spawning biomass (thousand mtons) estimated by the egg production method , HEP is the Historical Egg Production index of spawning biomass (Lo, 1985) and as modified to account for the reduced CalCOFI sampling pattern (MHEP). Z is the egg mortality associated with the HEP estimate and which was used in making the MHEP estimate. Sonar is based on the acoustic surveys conducted by CDF&G. Standard errors are in parentheses.

Year	EPM	HEP	MHEP	Z	SONAR
51	***	0.012 (0.12)	0.011 (0.06)	0.23 (2.18)	***
52	***	0.017 (0.11)	0.024 (0.14)	.09 (1.27)	***
53	***	0.066 (0.18)	0.035 (0.08)	.19 (0.54)	***
54	***	0.168 (0.19)	0.177 (0.18)	.12 (0.24)	***
55	***	0.316 (0.34)	0.360 (0.41)	.07 (0.26)	***
56	***	0.146 (0.65)	0.476 (2.21)	.33 (0.88)	***
57	***	0.364 (0.42)	0.444 (0.47)	.20 (0.25)	***
58	***	1.274 (1.18)	1.718 (1.23)	.43 (0.23)	***
59	***	0.992 (0.82)	1.777 (1.31)	.23 (0.20)	***
60	***	1.765 (0.77)	2.443 (1.20)	.24 (0.10)	***
61	***	0.653 (0.64)	0.706 (0.61)	.29 (0.22)	***
62	***	1.314 (1.17)	2.248 (1.66)	.19 (0.18)	***
63	***	2.275 (0.99)	2.967 (1.39)	.28 (0.09)	***
64	***	4.147 (2.68)	8.643 (4.59)	.42 (0.13)	***
65	***	4.019 (1.18)	8.177 (2.91)	.19 (0.06)	***
66	***	5.256 (1.80)	12.851 (5.12)	.42 (0.07)	***
67	***	***	***		***
68	***	***	***		***
69	***	3.821 (1.06)	5.431 (1.55)	.19 (0.06)	438.
70	***	***	***		275.
71	***	***	***		233.
72	***	1.657 (0.80)	3.450 (0.83)	.25 (0.11)	822.
73	***	***	***		1671.
74	***	***	***		947.
75	***	19.691(10.36)	16.707 (3.96)	.44 (0.11)	3086.
76	***	***	***		***
77	***	***	***		1984.
78	***	2.33 (4.48)	14.657 (6.53)	.59 (0.10)	392.
79	***	5.426 (2.62)	5.070 (2.19)	.48 (0.10)	292.
80	870.	2.671 (1.26)	2.548 (0.99)	.36 (0.08)	604.
81	635.	4.376 (2.08)	4.738 (1.78)	.38 (0.08)	567.
82	415.	3.29 (1.36)	1.684 (2.03)	.36 (0.09)	250.
83	652.	3.91 (1.17)	1.654 (1.27)	.46 (0.06)	532.
84	309.	2.85 (1.06)	2.567 (1.76)	.36 (0.08)	573.
85	521.	2.62 (0.67)	5.160 (2.16)	.28 (0.05)	1015.
86	***	***	7.558 (3.34)	.34 (0.12)[a]	***
87	***	***	7.234 (2.57)	.19 (0.08)[a]	***

[a]Z for 1986 and 1987 computed from the condensed CalCOFI area.

Table 2. United States fishery landings and weight at age.

Year	Mo	Landings (mtons)	Weight at age (g) age: 0	1	2	3	4	5+
64	1-2	0						
64	3-6	3482	0.0	12.9	17.5	21.0	24.5	28.8
64	7-8							
64	9-12	3484	11.2	16.6	19.4	21.8	24.4	26.3
65	1-2							
65	3-6	4122	0.0	12.9	17.5	21.0	24.5	28.8
65	7-8							
65	9-12	4124	11.2	16.6	19.4	21.8	24.4	26.3
66	1-3	4518	2.7	12.1	15.8	19.4	23.4	28.5
66	4-6	14440	6.7	13.6	17.4	20.1	22.9	28.0
66	7-9	4958	10.8	15.1	18.4	20.0	22.3	26.9
66	10-11	3851	12.3	17.1	19.4	21.7	23.9	26.3
67	12-2	16982	1.8	11.4	16.6	19.5	22.4	26.0
67	3-6	16934	5.9	11.7	17.7	22.3	28.1	33.3
67	7-9	3876	10.9	15.2	18.4	19.9	22.3	26.8
67	10-12	5307	12.1	16.9	19.5	21.8	24.1	26.8
68	1-3	979	2.8	12.1	15.7	19.2	23.2	28.5
68	4-6	3308	6.9	13.6	17.5	20.0	22.7	28.0
68	7-9	4487	10.9	15.2	18.4	19.9	22.3	26.8
68	10-1	13868	14.9	17.4	20.2	23.1	27.1	31.3
69	2-3	2445	3.8	14.2	16.0	21.0	20.7	24.1
69	4-5	10134	5.9	14.3	16.2	20.4	24.7	27.1
69	6-8	4676	9.1	13.7	18.3	20.1	22.1	27.8
69	9-12	47099	12.7	17.7	21.4	25.1	29.0	32.7
70	1	6089	1.3	13.8	17.8	20.0	26.1	27.8
70	2-5	23663	5.1	12.7	17.8	20.8	27.4	33.1
70	6-10	30437	11.8	17.5	21.6	24.3	29.3	27.8
70	11-12	32664	14.1	17.6	21.9	25.3	31.7	35.4
71	1	9128	1.3	13.5	18.7	22.5	25.9	32.5
71	2-5	10881	5.8	13.9	18.2	24.9	27.3	31.4
71	6-9	7359	9.9	14.5	18.3	20.0	22.2	27.1
71	10-12	19117	13.4	14.8	17.1	22.5	24.2	25.3
72	1-2	11734	1.9	12.5	15.1	18.2	24.3	27.8
72	3-5	16426	5.7	12.2	15.5	19.0	24.8	27.1
72	6-9	9508	9.9	14.6	18.3	20.0	22.2	27.0
72	10-12	30325	12.8	13.8	16.5	19.0	24.8	26.0
73	1-2	3483	1.7	8.9	11.1	13.7	14.0	27.9
73	3-6	36629	6.2	12.8	14.3	17.0	21.1	28.5
73	7-10	38266	8.5	14.0	16.2	18.5	21.6	29.3
73	11-12	47587	13.7	15.8	18.9	22.1	25.7	29.9
74	1-2	11824	2.0	10.7	12.9	15.4	17.7	25.0
74	3-6	18989	6.1	13.0	15.6	18.3	22.0	26.4
74	7-9	5084	11.1	15.4	18.4	19.9	22.3	26.6
74	10-1	61075	10.7	17.1	18.0	20.8	22.7	24.7
75	2-3	13491	3.2	13.7	17.6	18.7	21.4	26.1
75	4-6	34132	6.1	17.1	20.7	21.7	24.2	27.4

Table 2a. United States fishery landings and weight at age.

Year	Mo	Landings (mtons)	Weight at age (g) age: 0	1	2	3	4	5+
75	7-10	42862	15.1	18.1	19.5	20.3	22.6	23.6
75	11-1	60267	9.0	18.3	20.6	22.3	26.9	27.3
76	2-3	12557	3.9	10.4	19.6	22.9	25.0	30.4
76	4-6	19887	5.7	14.5	20.5	23.0	23.9	28.0
76	7-9	10229	11.6	17.1	19.1	20.7	22.2	24.6
76	10-1	61069	10.4	15.8	20.4	22.0	23.7	25.2
77	2	503	2.7	11.7	15.2	17.4	21.1	27.7
77	3-6	32294	4.7	13.9	15.5	19.1	22.5	26.5
77	7-9	13483	12.8	18.0	19.3	21.0	22.4	25.7
77	10-12	58869	12.2	18.4	20.3	22.1	22.9	26.2
78	1-3	832	3.0	12.1	15.7	19.2	23.2	28.5
78	4-6	3052	6.7	13.6	17.4	20.0	22.9	28.0
78	7-9	6031	12.2	17.0	18.9	25.0	22.3	26.4
78	10-12	7556	11.0	18.3	19.8	23.7	20.3	28.6
79	1-3	625	2.6	12.0	15.7	19.1	23.1	28.4
79	4-6	41754	6.5	14.3	18.6	22.5	24.8	24.9
79	7-9	4563	11.3	15.6	18.4	19.9	22.3	26.4
79	10-1	8591	8.8	19.2	23.0	20.0	24.9	26.6
80	2-3	207	3.5	12.2	15.7	19.1	23.1	28.6
80	4-6	26730	6.8	11.2	18.4	20.8	24.1	27.7
80	7-9	3374	11.0	15.2	18.4	19.9	22.3	26.8
80	10-1	27401	9.5	14.2	19.2	21.5	22.8	27.6
81	2-3	432	3.4	12.2	15.6	18.9	22.9	28.5
81	4-6	34699	6.5	14.0	15.8	19.7	21.9	28.6
81	7-9	2878	11.0	15.3	18.4	19.9	22.3	26.7
81	10-1	9151	7.6	17.0	18.3	20.4	25.1	26.8
82	2-3	375	3.4	12.2	15.6	19.0	23.0	28.6
82	4-6	40808	7.3	14.4	18.5	20.2	22.2	25.2
82	7-9	3044	10.6	14.8	18.4	20.0	22.3	27.2
82	10-12	2872	11.9	16.8	19.4	21.5	23.7	26.5
83	1-3	526	3.2	12.2	15.8	19.4	23.5	28.7
83	4-6	4561	7.4	13.4	17.8	20.1	22.4	27.9
83	7-9	2218	10.6	14.9	18.4	20.0	22.3	27.2
83	10-12	1182	12.2	17.0	19.4	21.7	23.9	26.5
84	1-3	427	2.5	11.9	15.7	19.0	22.9	28.3
84	4-6	3680	6.8	13.6	17.4	20.0	22.8	28.0
84	7-9	2266	10.5	14.9	18.4	20.0	22.3	27.2
84	10-12	929	12.0	16.8	19.4	21.5	23.8	26.5
85	1-3	503	2.8	12.0	15.6	18.8	22.7	28.3
85	4-6	1064	7.3	13.5	17.7	20.1	22.5	28.0
85	7-9	2727	10.7	15.0	18.4	20.0	22.3	27.1
85	10-12	1490	12.1	16.9	19.5	21.7	24.0	26.7
86	1-3	456	2.7	12.1	15.8	19.3	23.2	28.5
86	4-6	1648	6.4	13.8	17.2	19.9	23.1	28.1
86	7-9	2519	10.6	14.9	18.4	20.0	22.3	27.2
86	10-12	881	12.1	16.9	19.4	21.6	23.9	26.6

Table 3. Mexican fishery landings and weight at age.

Year	Mo	Landings (mtons)	Weight at age (g) age: 0	1	2	3	4	5+
no seasonal data								
64	3	4599	8.5	12.5	14.4	16.0	17.6	18.6
65	3	9171	8.5	12.5	14.4	16.0	17.6	18.6
66	3	13243	8.5	12.5	14.4	16.0	17.6	18.6
67	3	20104	8.5	12.5	14.4	16.0	17.6	18.6
68	3	14267	8.5	12.5	14.4	16.0	17.6	18.6
69	3	3871	8.5	12.5	14.4	16.0	17.6	18.6
70	3	27977	8.5	12.5	14.4	16.0	17.6	18.6
71	3	20079	8.5	12.5	14.4	16.0	17.6	18.6
72	3	30047	8.5	12.5	14.4	16.0	17.6	18.6
73	3	15424	8.5	12.5	14.4	16.0	17.6	18.6
begin seasonal data								
74	1-3	0						
74	4-6	12552	0.0	9.5	11.2	13.4	15.0	16.5
74	7-9	19115	8.5	12.5	14.4	16.0	17.6	18.6
74	10-12	11143	8.2	12.8	14.6	18.1	19.2	18.6
75	1-3	6897	1.5	8.7	13.2	15.9	17.0	20.8
75	4-6	21191	7.0	10.8	13.9	15.5	16.8	20.8
75	7-8	20733	6.3	11.8	14.7	15.6	17.4	20.8
75	9-12	8056	6.0	11.3	14.1	15.2	17.9	20.8
76	1-3	253	2.2	8.9	13.3	15.8	17.0	20.8
76	4-5	2492	5.0	10.0	13.5	15.6	16.8	20.8
76	6-9	36686	6.4	11.5	14.6	15.5	17.7	20.8
76	10-1	38745	7.7	11.3	14.3	15.6	17.5	20.8
77	2-3	2204	2.7	9.4	13.4	15.8	17.0	20.8
77	4-5	9884	5.0	10.0	13.5	15.6	16.8	20.8
77	6-8	90522	6.3	11.6	14.6	15.6	17.5	20.8
77	9-1	37692	6.5	11.5	14.2	15.7	17.7	20.8
78	2-3	0	0.0	0.0	0.0	0.0	0.0	0.0
78	4-5	12089	5.2	10.0	13.5	15.5	16.7	20.8
78	6-8	72637	9.2	13.6	15.4	17.3	18.8	20.8
78	9-1	56261	10.4	14.6	16.3	19.2	18.0	20.8
79	2-3	0	0.0	0.0	0.0	0.0	0.0	0.0
79	4-6	78899	6.9	11.6	12.8	15.0	17.2	20.7
79	7-8	45929	7.4	11.8	13.3	16.6	17.5	20.8
79	9-1	81238	7.1	12.0	13.6	16.9	17.9	20.8
80	2-3	139	2.8	9.4	13.4	15.8	17.0	20.8
80	4-5	4611	5.4	10.2	13.9	15.7	17.0	20.8
80	6-8	130810	7.7	12.9	16.1	17.0	18.7	20.8
80	9-1	110940	8.5	13.0	16.0	17.7	18.8	20.8
81	2-3	0	0.0	0.0	0.0	0.0	0.0	0.0
81	4-6	71423	7.4	10.7	12.6	14.3	15.4	20.8
81	7-9	144543	7.6	10.7	12.6	14.0	16.2	20.8
81	10-1	39420	8.4	11.4	13.3	14.7	14.9	20.8

Table 3a. Mexican fishery landings and weight at age.

Year	Mo	Landings (mtons)	Weight at age (g) age: 0	1	2	3	4	5+
82	2-3	0	0.0	0.0	0.0	0.0	0.0	0.0
82	4-5	27240	5.3	12.4	14.3	15.9	16.5	20.7
82	6-8	105296	8.2	12.1	13.5	14.8	15.3	20.8
82	9-10	24695	7.3	11.9	13.5	14.7	15.4	20.8
83	11-3	24418	1.1	6.7	9.0	10.1	12.1	19.2
83	4-5	35725	5.3	7.1	8.7	9.1	16.7	20.8
83	6-8	18308	6.7	8.7	10.2	11.0	17.2	20.8
83	9-2	21341	3.3	7.1	8.0	9.7	16.1	20.8
84	3-4	590	4.4	6.9	8.1	11.1	17.0	20.8
84	5-6	36495	5.6	8.6	13.7	16.0	17.5	20.8
84	7	25465	4.9	9.2	12.7	12.1	17.2	20.8
84	8-1	38546	5.0	8.5	12.0	15.9	17.8	20.8
85	2	0	0.0	0.0	0.0	0.0	0.0	0.0
85	3-6	59348	6.3	14.1	15.7	18.3	18.7	20.8
85	7	17894	6.4	18.8	20.1	26.2	25.0	20.8
85	8-1	44547	7.1	18.5	20.9	22.3	22.7	20.8
86	2-3	211	2.7	9.4	13.4	15.8	17.0	20.8
86	4-5	7334	4.7	8.4	13.8	16.4	16.6	19.8
86	6-7	36648	8.1	13.1	16.0	20.7	20.9	22.3
86	8-12	51478	5.3	12.9	15.5	19.8	19.2	20.8

Table 4. Age composition for US fishery, Mexican fishery and US survey. Fishery age composition is in numbers of fish at age. Fractional fish are due to the weighting of raw monthly age compositions by the monthly landings. Survey age composition is expressed in thousandths and should be scaled by N aged.

Year	Qtr	Type	Age: 0	1	2	3	4	5+	N aged
67	1	US-F	0.0	39.0	224.3	662.3	704.0	239.0	1870
67	2	US-F	0.0	42.3	167.0	265.6	165.7	96.4	739
68	1	US-S	0.0	422.0	305.0	149.0	111.0	14.0	105
68	2	US-S	0.0	144.0	248.0	189.0	259.0	161.0	245
68	4	US-F	39.1	358.1	285.0	92.4	60.8	6.2	845
69	1	US-F	0.0	62.7	73.7	26.0	6.6	10.1	179
69	2	US-F	0.0	200.8	389.9	119.7	50.1	30.5	789
69	4	US-F	101.2	722.6	1664.8	423.3	80.1	12.0	3003
70	1	US-F	0.0	167.0	352.0	207.0	44.0	16.0	786
70	1	US-S	0.0	359.0	322.0	250.0	47.0	22.0	206
70	2	US-F	0.0	1191.0	528.9	338.3	73.7	18.1	2153
70	3	US-F	4.5	411.3	902.0	302.9	34.3	3.0	1657
70	4	US-F	42.0	682.0	756.0	480.0	57.0	9.0	2024
71	1	US-F	0.0	69.0	367.0	304.0	243.0	67.0	1050
71	1	US-S	0.0	196.0	301.0	307.0	164.0	33.0	173
71	2	US-F	0.0	54.4	89.6	95.8	51.7	20.5	312
71	2	US-S	0.0	223.0	281.0	300.0	132.0	64.0	171
71	4	US-F	62.5	477.2	365.7	94.5	24.1	0.7	1029
72	1	US-F	0.0	106.8	890.9	366.4	147.7	44.0	1557
72	2	US-F	0.0	154.5	424.9	192.8	79.1	15.6	867
72	2	US-S	0.0	122.0	412.0	253.0	119.0	94.0	190
72	4	US-F	74.1	500.2	1561.2	431.6	37.8	9.1	2616
73	1	US-S	0.0	43.0	377.0	457.0	112.0	11.0	249
73	2	US-F	0.0	425.9	864.5	1237.8	455.6	134.1	3116
73	2	US-S	0.0	35.0	219.0	406.0	255.0	86.0	190
73	3	US-F	6.0	319.3	985.6	907.5	153.8	10.8	2383
73	4	US-F	27.6	269.5	935.9	1027.4	264.5	24.0	2548
74	1	US-F	0.0	263.9	607.5	471.9	260.1	37.8	1640
74	2	US-F	0.0	157.0	274.7	174.2	134.0	42.1	782
74	2	US-S	0.0	28.0	144.0	333.0	396.0	100.0	290
74	4	US-F	43.2	579.7	1694.7	966.9	301.0	18.9	3611
75	1	US-F	0.0	154.9	231.0	252.1	170.2	83.8	892
75	1	MX-F	0.0	49.8	65.2	186.6	60.7	9.7	372
75	1	US-S	0.0	84.0	153.0	273.0	262.0	228.0	220
75	2	US-F	0.0	52.9	317.3	656.8	598.6	343.5	1970
75	2	MX-F	1.3	8.0	77.2	144.4	49.5	7.7	288
75	3	US-F	13.0	369.7	1187.9	738.5	162.9	27.2	2498
75	3	MX-F	4.3	16.5	70.9	114.0	37.5	5.7	249
75	4	US-F	59.9	297.0	1345.2	1342.5	531.7	46.5	3625
75	4	MX-F	21.5	24.5	37.0	62.0	25.2	5.8	176

Year	Qtr	Type	Age: 0	1	2	3	4	5+	N aged
76	1	US-F	0.0	52.1	57.7	180.1	263.0	257.7	809
76	2	US-F	0.0	7.0	89.1	299.9	467.2	286.8	1151
76	2	MX-F	0.0	27.4	100.3	189.1	66.7	8.5	392
76	2	US-S	0.0	16.0	24.0	151.0	430.0	380.0	320
76	3	US-F	0.0	36.0	67.0	76.0	13.0	1.0	193
76	3	MX-F	170.3	144.2	151.1	175.1	78.5	10.7	730
76	4	US-F	306.2	255.2	579.8	1086.1	535.3	93.3	2856
76	4	MX-F	376.2	59.9	81.5	36.8	10.6	0.0	565
77	1	MX-F	0.0	93.0	39.5	113.2	51.3	0.0	297
77	1	US-S	0.0	450.0	47.0	96.0	216.0	191.0	470
77	2	US-F	0.0	908.7	250.2	187.8	264.1	212.2	1823
77	2	MX-F	0.0	98.4	47.3	66.1	55.4	24.8	292
77	3	US-F	5.0	158.0	76.0	40.0	50.0	10.0	339
77	3	MX-F	34.1	215.2	166.3	233.0	182.1	40.2	871
77	4	US-F	262.9	886.3	506.8	379.6	358.3	77.0	2471
77	4	MX-F	115.2	183.1	115.4	112.2	51.9	15.2	593
78	1	US-S	0.0	96.0	459.0	160.0	149.0	135.0	396
78	3	MX-F	146.5	151.4	1043.1	62.8	39.0	23.2	1466
78	4	US-F	71.4	107.3	114.5	4.9	7.3	1.7	307
78	4	MX-F	1353.8	170.6	303.6	9.4	8.1	3.5	1849
79	1	US-S	0.0	652.0	95.0	180.0	64.0	8.0	508
79	2	US-F	0.0	2453.2	720.9	432.7	63.8	18.5	3688
79	2	MX-F	6.9	1096.8	430.2	146.3	7.0	1.9	1689
79	2	US-S	0.0	727.0	132.0	97.0	25.0	18.0	328
79	3	MX-F	48.1	799.9	155.1	49.6	2.2	0.0	1055
79	4	MX-F	744.1	1112.4	135.7	45.1	1.6	0.0	2039
80	1	US-S	0.0	348.0	501.0	120.0	22.0	8.0	610
80	2	US-F	0.0	915.6	1170.1	159.6	23.2	2.4	2270
80	2	MX-F	0.0	241.0	202.7	21.5	14.8	0.0	480
80	3	MX-F	15.9	763.2	1089.2	107.3	20.5	0.0	1996
80	4	US-F	135.2	1008.6	736.6	77.6	10.0	0.0	1966
80	4	MX-F	750.5	723.5	607.9	57.5	3.7	0.0	2143
81	1	US-S	0.0	453.0	305.0	205.0	34.0	2.0	555
81	2	US-F	0.0	1177.1	902.8	583.3	59.4	2.0	2724
81	2	MX-F	12.0	1490.3	789.6	282.1	24.1	0.0	2598
81	2	US-S	0.0	297.0	316.0	379.0	8.0	0.0	460
81	3	MX-F	130.8	1246.4	583.0	215.2	21.6	0.0	2197
81	4	US-F	8.3	125.5	168.8	29.4	0.0	0.0	332
81	4	MX-F	441.2	737.6	411.7	148.4	14.6	3.5	1757
82	1	US-S	0.0	93.0	360.0	477.0	68.0	0.0	651
82	2	US-F	0.0	389.7	849.9	1137.8	293.2	2.9	2672
82	2	MX-F	0.0	70.1	367.4	154.2	45.0	0.2	637
82	3	MX-F	57.1	374.5	641.5	179.7	26.3	0.0	1279
82	4	MX-F	317.3	146.9	164.2	29.6	1.9	0.0	660
83	1	MX-F	0.0	399.1	223.1	54.8	3.1	0.0	680
83	1	US-S	0.0	742.0	112.0	108.0	38.0	0.0	582
83	2	MX-F	0.0	431.6	41.3	7.1	0.0	0.0	480
83	3	MX-F	56.4	431.4	44.2	8.1	0.0	0.0	540
83	4	MX-F	393.2	369.7	49.1	7.9	0.0	0.0	820

Year	Qtr	Type	Age: 0	1	2	3	4	5+	N aged
84	1	US-S	0.0	348.0	585.0	53.0	13.0	0.0	518
84	2	MX-F	30.7	510.1	269.5	23.0	5.7	0.0	839
84	3	MX-F	93.0	217.0	29.0	1.0	0.0	0.0	340
84	4	MX-F	1298.9	449.2	31.9	0.0	0.0	0.0	1780
85	1	US-S	0.0	718.0	191.0	76.0	5.0	8.0	464
85	2	MX-F	0.0	644.4	571.5	176.4	13.6	4.0	1410
85	4	MX-F	755.6	168.1	113.0	32.9	6.4	0.0	1076
86	1	US-S	0.0	170.0	598.0	203.0	24.0	5.0	790
86	2	MX-F	0.0	476.9	130.0	57.2	13.2	2.6	680
86	3	MX-F	90.5	828.6	67.3	9.3	3.2	1.1	1000
86	4	MX-F	779.2	292.7	58.6	21.6	8.0	0.0	1160

Table 5. Time series of environmental deviations and weight at age deviations. Deviations are calculated from monthly means then averaged into quarters. Environmental deviations are lagged -1 month (e.g. quarter 1 contains average Dec - Feb deviation). Temp is the surface temperature at the SIO pier. Sea level is the sea level at the SIO pier (Prager and MacCall, 1986). WTDEV-US and WTDEV-MX are average weight at age deviations for ages 2-4 based on data from the commercial reduction fishery at San Pedro in the U.S. and at Ensenada in Mexico.

Year	Qtr.	Temp.	Sea Level
51	1	-.523	-.863
51	2	-.084	-.147
51	3	-.221	.355
51	4	-.289	.626
52	1	-.336	-.188
52	2	-.290	-.241
52	3	-.816	-.711
52	4	-1.027	-.026
53	1	-.461	-.023
53	2	-1.011	-.283
53	3	-.300	-.243
53	4	-.908	-.111
54	1	-.149	-.087
54	2	-.435	.053
54	3	.553	.399
54	4	-.574	-.449
55	1	-.635	-.496
55	2	-.714	-.144
55	3	.036	-.130
55	4	-.134	-1.117
56	1	-1.322	-1.256
56	2	-.851	-.263
56	3	-.229	-.049
56	4	-.366	-.632
57	1	.495	-.136
57	2	-.002	.461
57	3	.866	1.439
57	4	.097	.870
58	1	1.901	1.372
58	2	.956	1.255
58	3	-.274	.621
58	4	1.437	1.427
59	1	1.592	1.111
59	2	1.655	.930
59	3	1.275	.858
59	4	1.523	1.083
60	1	.282	.265
60	2	.500	.193
60	3	-1.092	-.011
60	4	-.204	.023

Year	Qtr.	Temp.	Sea Level	WTDEV-US	WTDEV-MX
61	1	.107	.185		
61	2	-.183	-.189		
61	3	-.622	-.048		
61	4	-.979	-.370		
62	1	-.634	.275		
62	2	-.666	-.599		
62	3	-1.260	***		
62	4	-.355	***		
63	1	.156	.216		
63	2	-.494	-.231		
63	3	-.131	.684		
63	4	.397	.779		
64	1	.900	.188		
64	2	-.935	-.789		
64	3	-.402	-.735		
64	4	-.797	-.599		
65	1	-1.122	-.056		
65	2	.295	.476		
65	3	-1.351	.212		
65	4	.020	.841		
66	1	-.074	.836		
66	2	.274	.634		
66	3	.532	.607		
66	4	-.065	-.077		
67	1	-.178	.231	.34	
67	2	-.680	-.433	.56	
67	3	.021	.277	***	
67	4	1.050	.139	***	
68	1	-.005	.436	***	
68	2	.142	.084	***	
68	3	-.007	-.206	***	
68	4	-.040	.332	.79	
69	1	-.141	.591	1.01	
69	2	-.547	.360	-.29	
69	3	-.563	.333	***	
69	4	-.283	.788	1.99	
70	1	-.124	-.324	1.68	
70	2	.059	-.115	.18	
70	3	-.403	.004	2.37	
70	4	-.107	-.111	1.95	
71	1	-.819	-.528	2.95	
71	2	-1.580	-.285	1.38	
71	3	.958	.314	***	
71	4	-1.022	.121	-1.23	
72	1	-1.716	-.056	-.25	
72	2	-.164	.735	-1.31	
72	3	.451	1.573	***	
72	4	.156	1.523	-2.90	
73	1	1.051	1.387	***	
73	2	-.354	.056	-2.62	
73	3	-.489	-.300	-2.37	
73	4	-1.285	-1.192	-.45	

Year	Qtr.	Temp.	Sea Level	WTDEV-US	WTDEV-MX
74	1	-1.114	-.455	-2.30	
74	2	-.494	.767	-1.20	
74	3	-.425	.922	***	
74	4	.185	.286	-1.06	
75	1	-1.041	-.370	1.34	
75	2	-1.668	.160	2.40	
75	3	-1.481	-.186	.47	
75	4	-1.494	-.269	.69	
76	1	-.646	.068	2.12	
76	2	-.412	.904	2.77	
76	3	-.259	.848	.69	
76	4	1.539	1.412	.03	
77	1	2.144	1.089	***	
77	2	-.282	-.073	.28	
77	3	-.508	.351	1.17	
77	4	.474	.819	1.12	
78	1	1.562	1.730	***	
78	2	1.181	1.217	***	
78	3	-.422	.219	***	.84
78	4	.783	.886	.85	2.36
79	1	-.546	.880	***	***
79	2	-.301	.784	0.95	0.41
79	3	.157	.470	***	.29
79	4	.086	.302	***	.34
80	1	.524	1.693	***	***
80	2	.296	1.408	-.18	0.22
80	3	-.999	.797	***	.74
80	4	-.883	.481	-1.26	1.15
81	1	.242	.713	***	***
81	2	1.061	1.590	-.44	-.48
81	3	1.472	1.115	***	-1.29
81	4	.073	.380	-.74	-.14
82	1	-.093	.387	***	***
82	2	.282	1.311	.51	.59
82	3	-.131	1.221	***	-.42
82	4	.559	2.752	***	.03
83	1	1.393	3.158	***	-3.24
83	2	.808	2.607	***	-3.11
83	3	.200	3.471	***	-3.03
83	4	1.965	2.480	***	-4.41
84	1	.924	1.068	***	-3.00
84	2	1.091	2.159	***	-1.53
84	3	2.184	2.464	***	-2.26
84	4	2.000	1.616	***	-3.54
85	1	-.427	***	***	***
85	2	.015	***	***	2.89
85	3	.614	***	***	***
85	4	.953	***	***	3.94
86	1	.602	***	***	***
86	2	1.258	***	***	-.97
86	3	.130	***	***	1.67
86	4	.734	***	***	1.93
87	1	1.230	***	***	***

Table 6. 1986 Mexican fishery data. Obtained through contract with Living Marine Resources Fisheries Research, Inc.

Month	Landings (mtons)		Age Composition and Weight at Age 0	1	2	3	4+
Jan	746	N		44	11	4	0
		wt		6.3g	11.7	14.8	
Feb	106	N					
		wt					
Mar	105	N					
		wt					
Apr	5097	N		418	69	40	13
		wt		8.1	13.2	16.4	17.4
May	2237	N		75	47	15	3
		wt		9.4	14.3	16.3	14.9
Jun	15815	N	7	330	35	5	3
		wt	8.9	13.4	16.5	19.9	21.4
Jul	20833	N	90	495	30	5	1
		wt	8.0	12.9	15.2	21.9	19.5
Aug	32226	N	307	143	32	13	5
		wt	5.6	11.8	14.9	19.6	18.7
Sep	11079	N	300	71	9	0	0
		wt	3.8	15.8	16.2		
Oct	7412	N	209	57	9	4	1
		wt	6.5	15.3	19.7	26.7	29.4
Nov	761	N					
		wt					
Dec	0	N					
		wt					

Table 7. Time series of estimated biomass and recruitment. Biomass estimates are in units of thousand metric tons as of Feb. 15 of the indicated year. Recruitment estimates are in units of 50 billion age 0 fish as of July 1 of the indicated year.

Year	Total Biomass	Spawn. Biomass	Recruitment
1964	767	758	0.580
1965	722	598	.188
1966	548	524	.183
1967	381	364	.557
1968	375	355	.528
1969	407	378	.619
1970	437	335	1.761
1971	770	346	1.730
1972	1105	643	2.456
1973	1522	1494	2.223
1974	1737	1201	.845
1975	1447	1254	.375
1976	1041	993	1.118
1977	846	845	.292
1978	472	471	2.238
1979	873	579	1.693
1980	797	789	1.533
1981	827	789	.516
1982	470	433	1.673
1983	543	526	.766
1984	384	377	1.577
1985	699	546	1.462
1986	773	764	3.191
1987	1244	1212	---

Table 8. Patterns of age-specific availability. Cold-large is defined as long-term temperature deviation of -0.3, short-term temperature deviation of -2.0, and weight at age deviation of 2.0. Warm-small is defined as long-term temperature deviation of 0.3, short-term temperature deviation of 2.0, and weight at age deviation of -2.0.

	US Fishery			Mex Fishery			US Survey		
	COLD BIG	NULL	WARM[1] SMALL	COLD[2] BIG	NULL	WARM SMALL	COLD BIG	NULL	WARM SMALL
AGE									
1.00	.00	.03	.07	.20	.18	1.00	.01	.07	.23
2.00	.06	.26	.49	.35	.61	.96	.06	.20	.48
3.00	.24	.76	1.00	.59	1.00	.35	.24	.59	1.00
4.00	1.00	1.00	.19	1.00	.39	.13	1.00	1.00	.17
5.00+[3]	.58	.17	.03	.91	.15	.05	.72	.13	.02
1.25	.01	.09	.24	.20	.29	1.00	.01	.04	.16
2.25	.06	.25	.49	.35	1.00	.45	.04	.13	.40
3.25	.24	.73	1.00	.59	.95	.16	.20	.47	1.00
4.25	1.00	1.00	.19	1.00	.37	.06	1.00	1.00	.19
5.25+	.55	.17	.03	.64	.14	.02	.72	.13	.02
0.50	--	--	--	.01	.01	.04			
1.50	.02	.12	.49	.20	.29	1.00			
2.50	.08	.34	1.00	.35	1.00	.36			
3.50	.35	1.00	.65	.59	.55	.13			
4.50	1.00	.31	.11	1.00	.21	.05			
5.50+	.17	.05	.02	.45	.08	.02			
0.75	.00	.00	.02	.16	.10	.50			
1.75	.05	.13	.49	.27	.35	1.00			
2.75	.19	.37	1.00	.45	1.00	.36			
3.75	.78	1.00	.35	.77	.39	.13			
4.75	1.00	.17	.06	1.00	.15	.05			
5.75+	.17	.03	.01	.41	.06	.02			

[1] Few warm-small quarters sampled in US fishery
[2] Few cold-big quarters sampled in Mexican fishery
[3] Age 5+ was compressed into age 4+ beginning in 1979.

FIGURE LEGENDS

Figure 1. Availability of older age groups to the Mexican fishery relative to the mean size of age 2 anchovy. Ages 1-3 have similar weight at age deviations. High variability in the old fish fraction at higher mean weight levels is due to variability in abundances of yearclasses which contribute to the fraction.

Figure 2. A change in the relation between sea level and temperature at SIO pier seems to have occurred in about 1978. Plotted values are quarterly averages of monthly de-seasonalized observations.

Figure 3. Quarterly deviations in weight at age are related to quarterly deviations in temperature at the SIO pier. Weight at age data for 1967-77 are entirely from the U.S. fishery and show no apparent relationship. Later weight at age data are primarily from the Mexican fishery at Ensenada and show a decline in size related to increasing water temperature. In 1986 (circled points) weight at age was larger than expected based on the temperature.

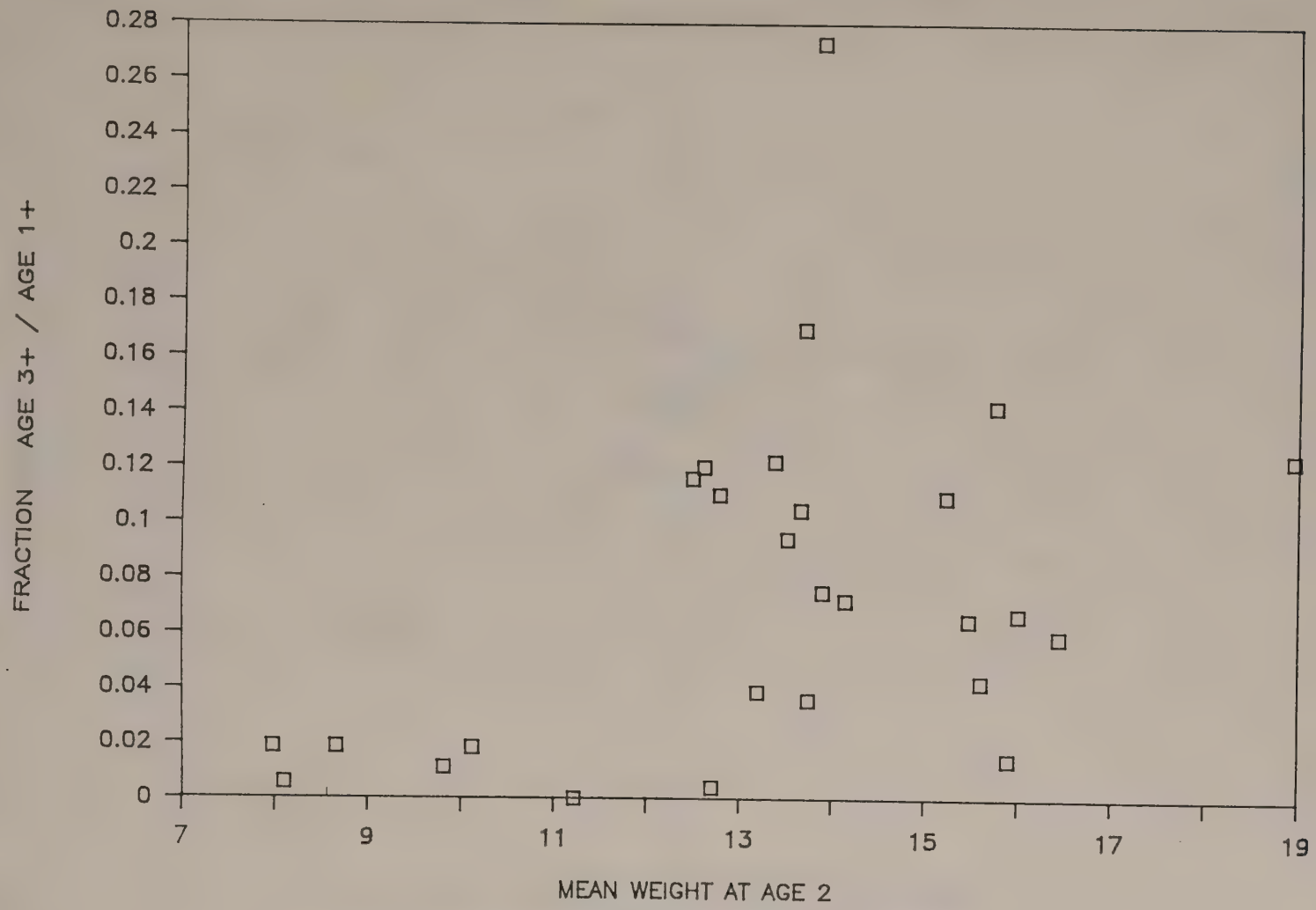
Figure 4. Estimated time series of spawning biomass and observations made by the Egg Production Method.

Figure 5. Estimated and observed time series of Historical Egg Production (Lo, 1985) and HEP modified to the current restricted CalCOFI survey area.

Figure 6 a-h. Recent observed (left column) and estimated (right column) age compositions. The fit to the US survey age composition in the first quarter of 1986 (fig. e) was among the worst in the entire time series. Note that relative availability at age 4+ (Table 8) matters little to the goodness of fit because of the low abundance of this age group. Recent estimated true fractions in this age group were: 1985 - 0.022, 1986 - 0.057, 1987 - 0.023.

Figure 7. Relationship between deviations in the original HEP spawning biomass index and oversampling of the Feb-Apr period. Because spawning in January is reduced (MacCall and Prager, 1987), a positive correlation is expected here.

Figure 8. Percentage of larvae in Mexico (PFMC, 1983 and subsequent EPM surveys) declines in warm years. This relationship is further evidence for alongshore movement of the anchovy stock in response to climatic conditions.



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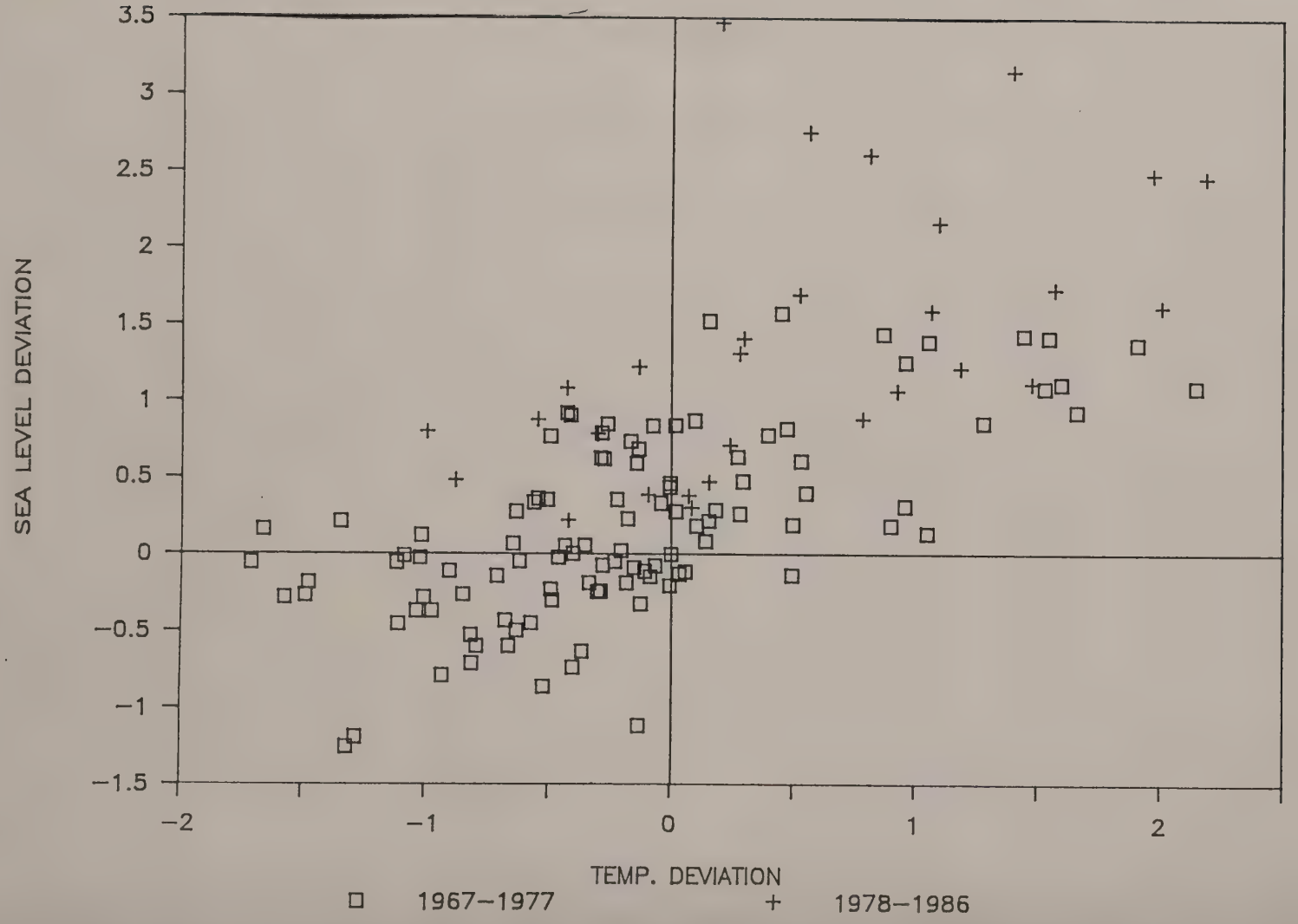

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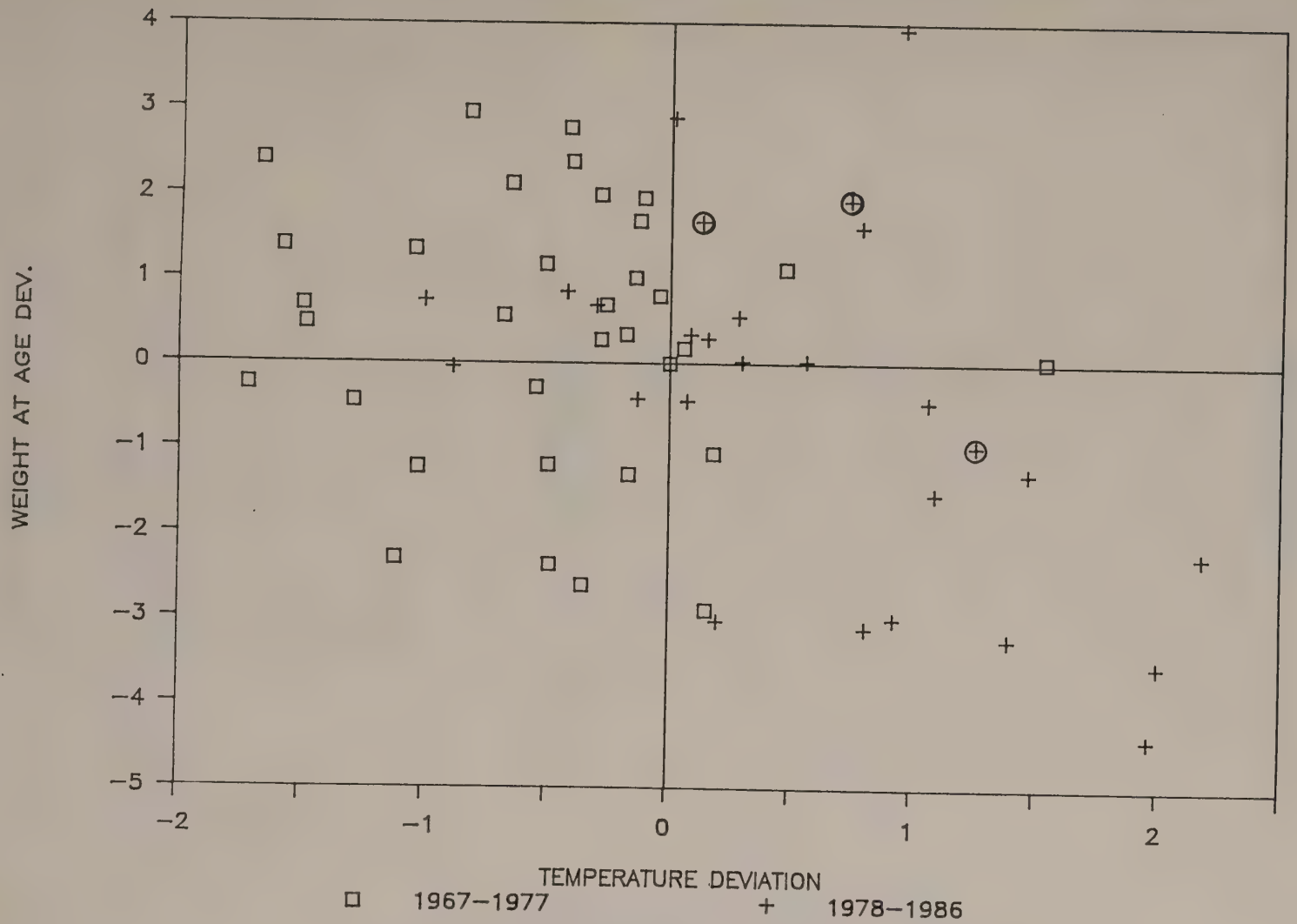
TRANS–BOUNDARY STOCK DISTRIBUTION



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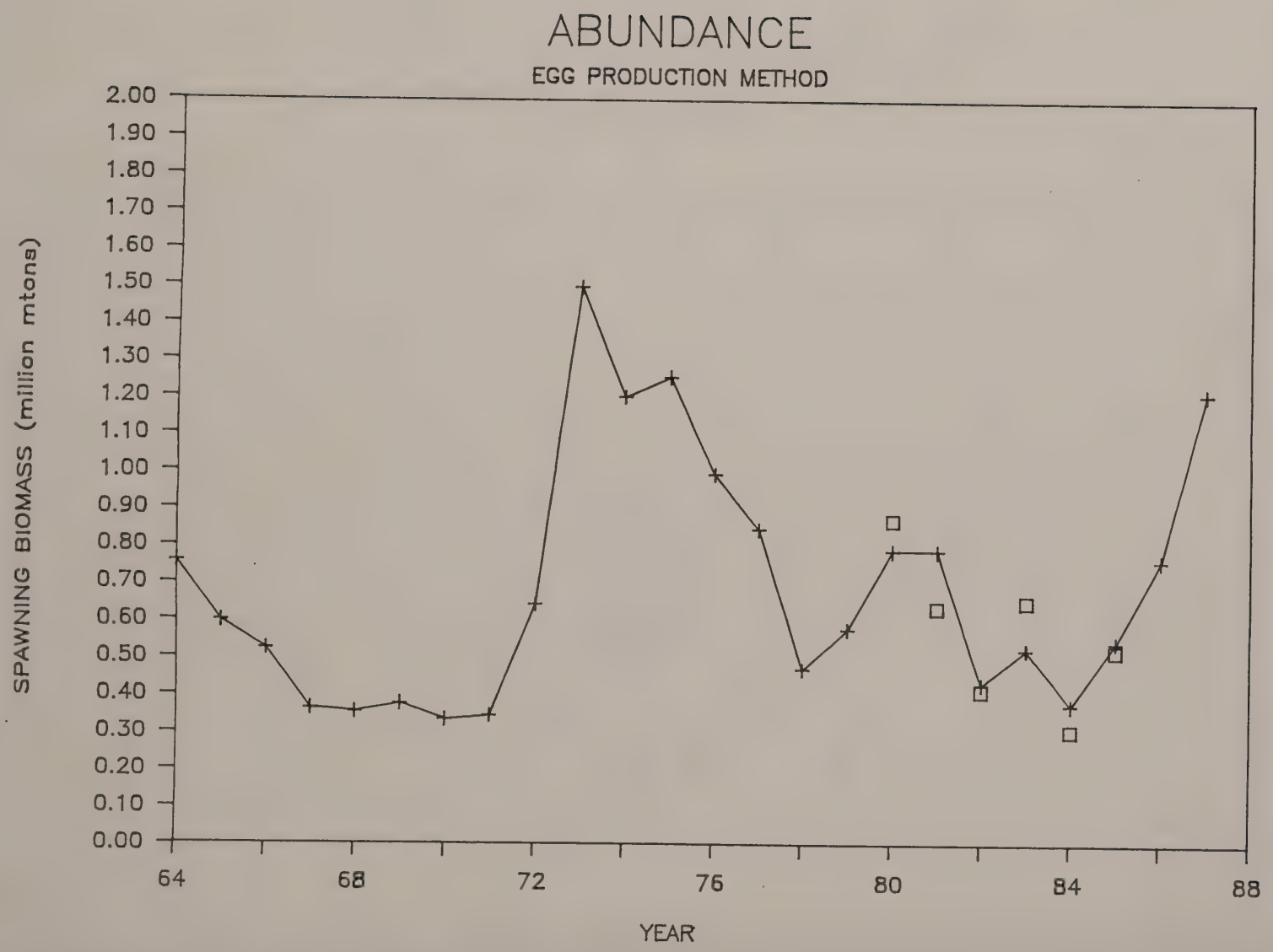

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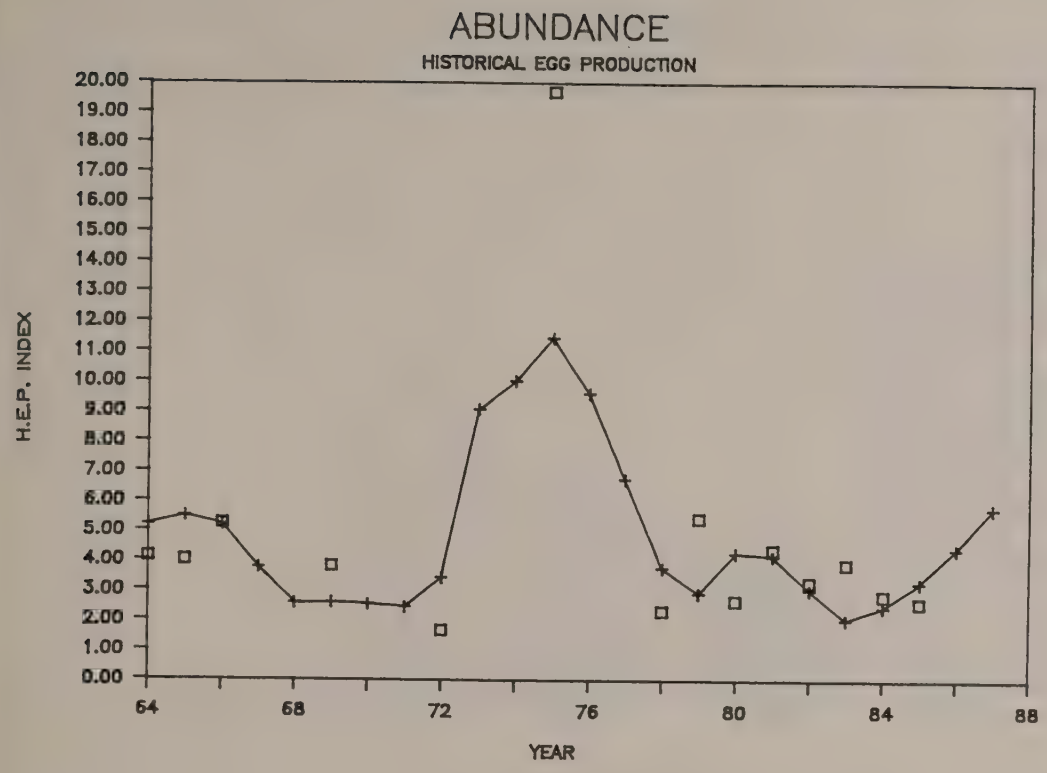

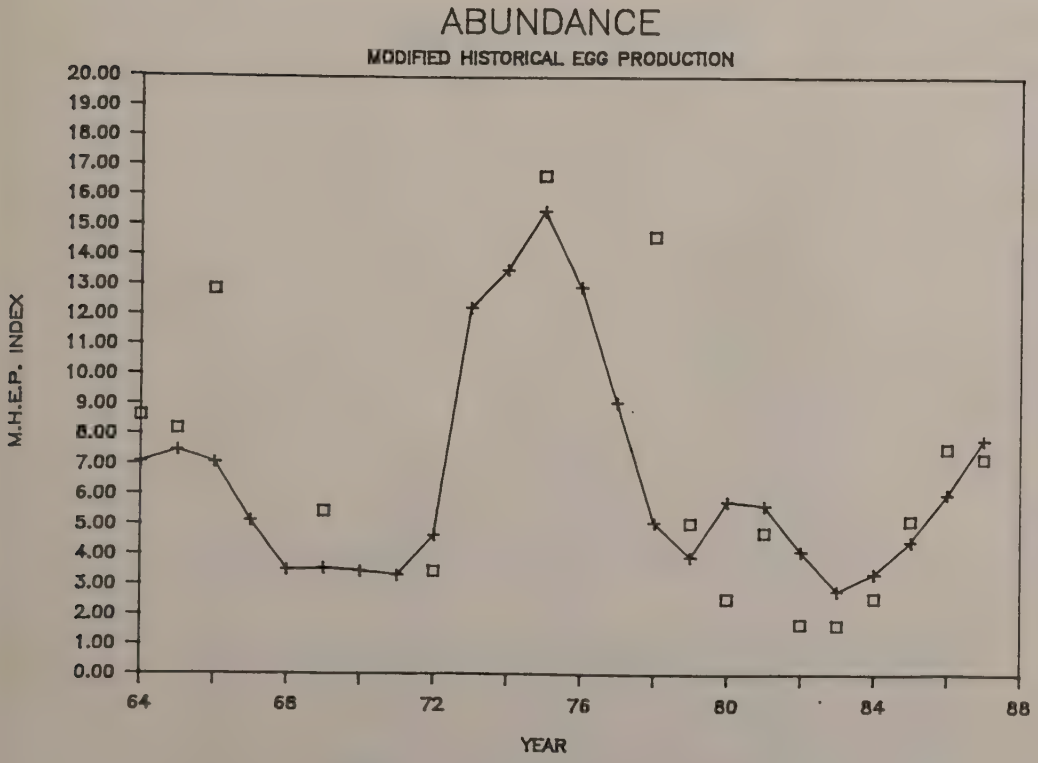

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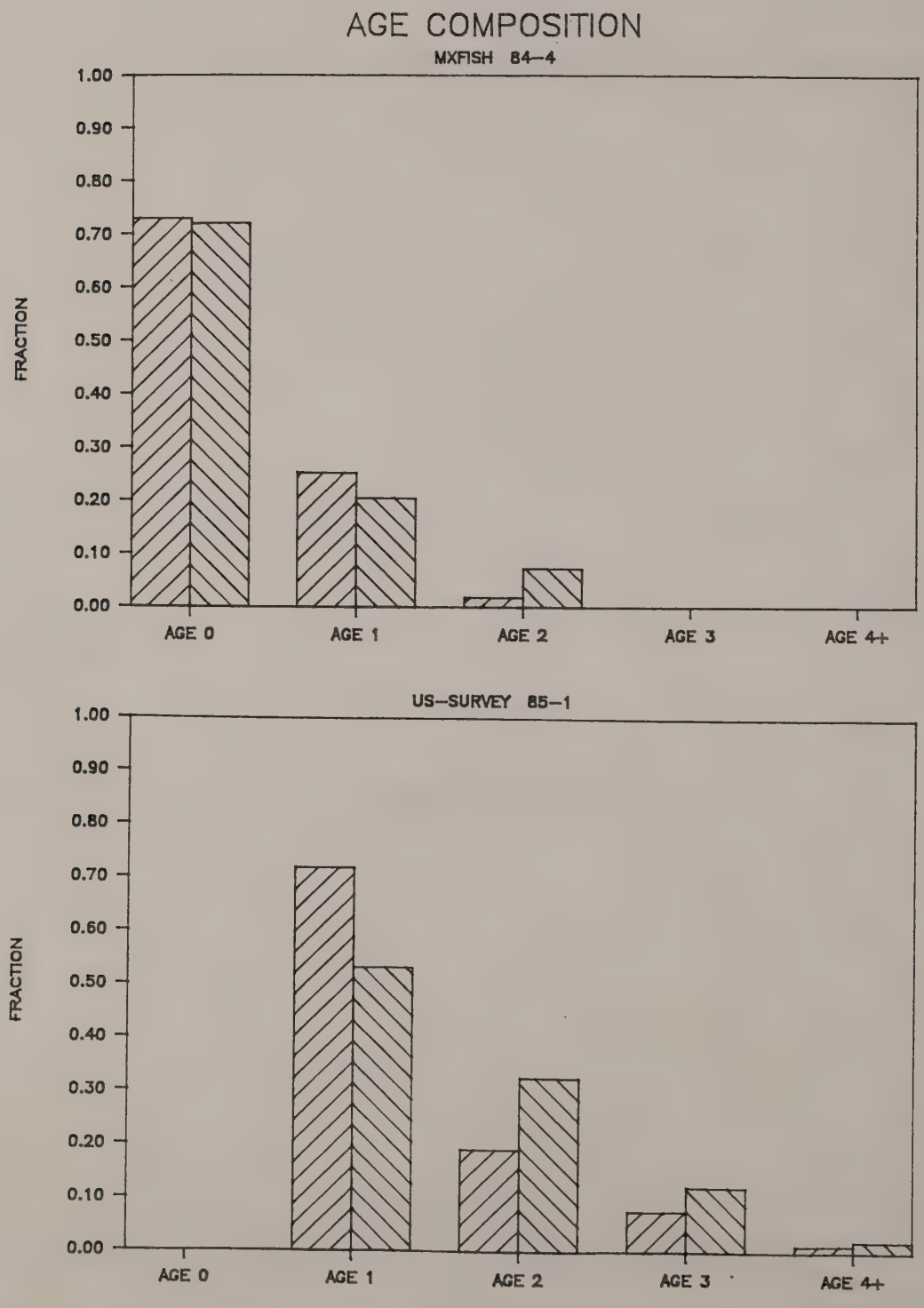

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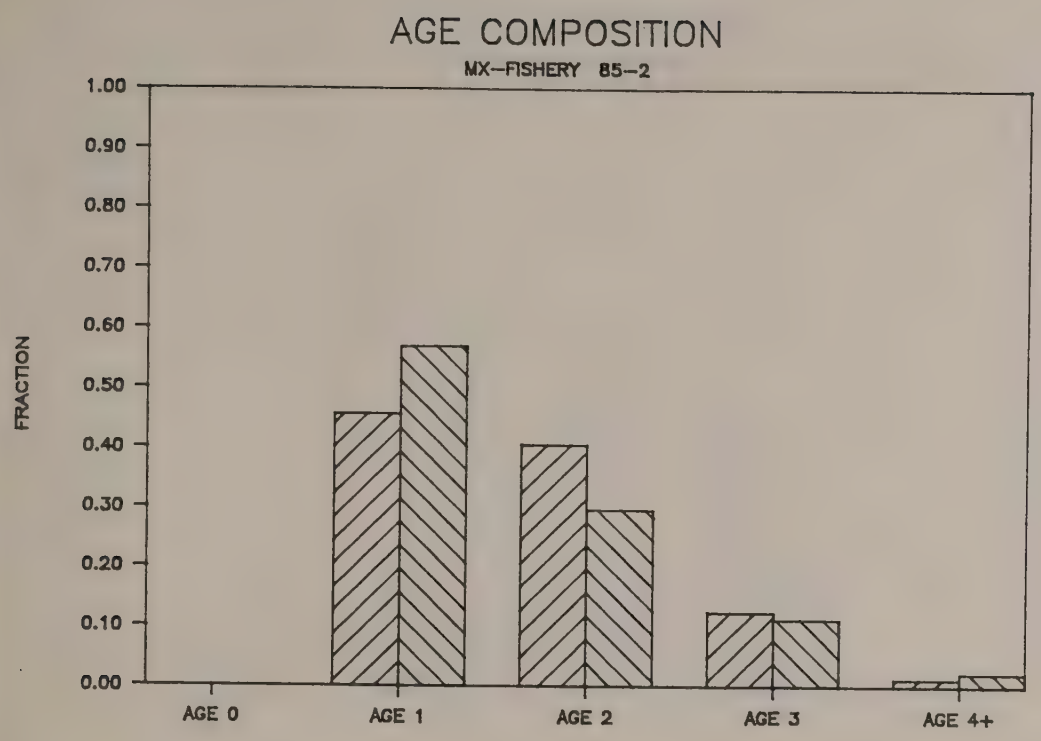
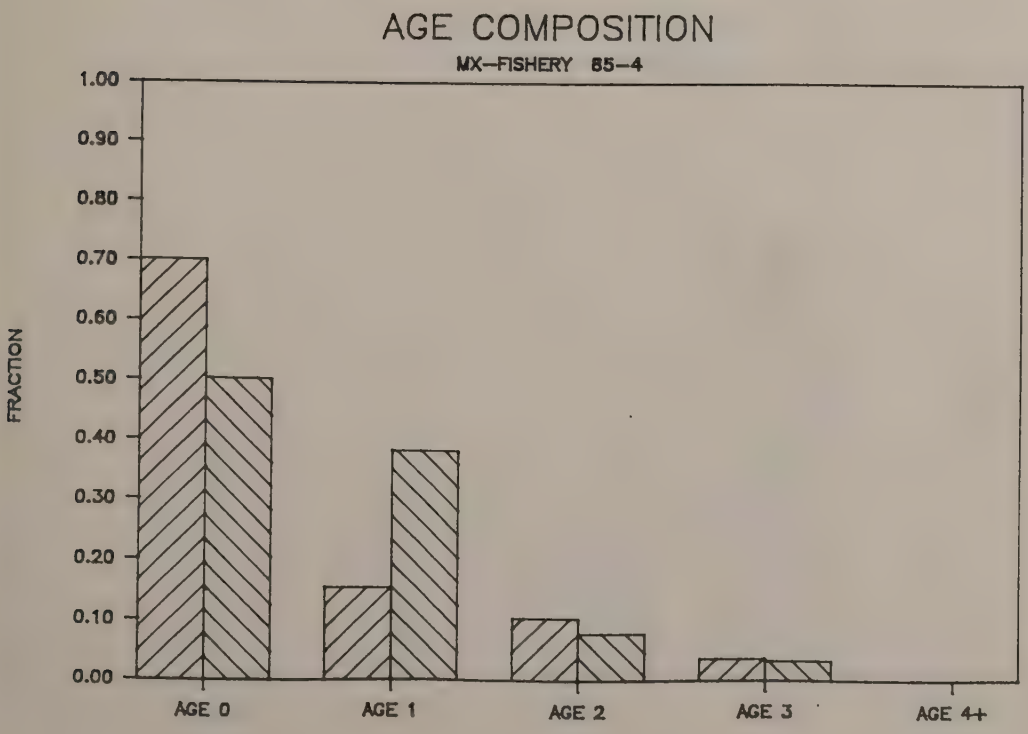

AGE COMPOSITION
MX-FISHERY 85-2
FRACTION
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
AGE 0
AGE 1
AGE 2
AGE 3
AGE 4+


AGE COMPOSITION
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0.50
0.40
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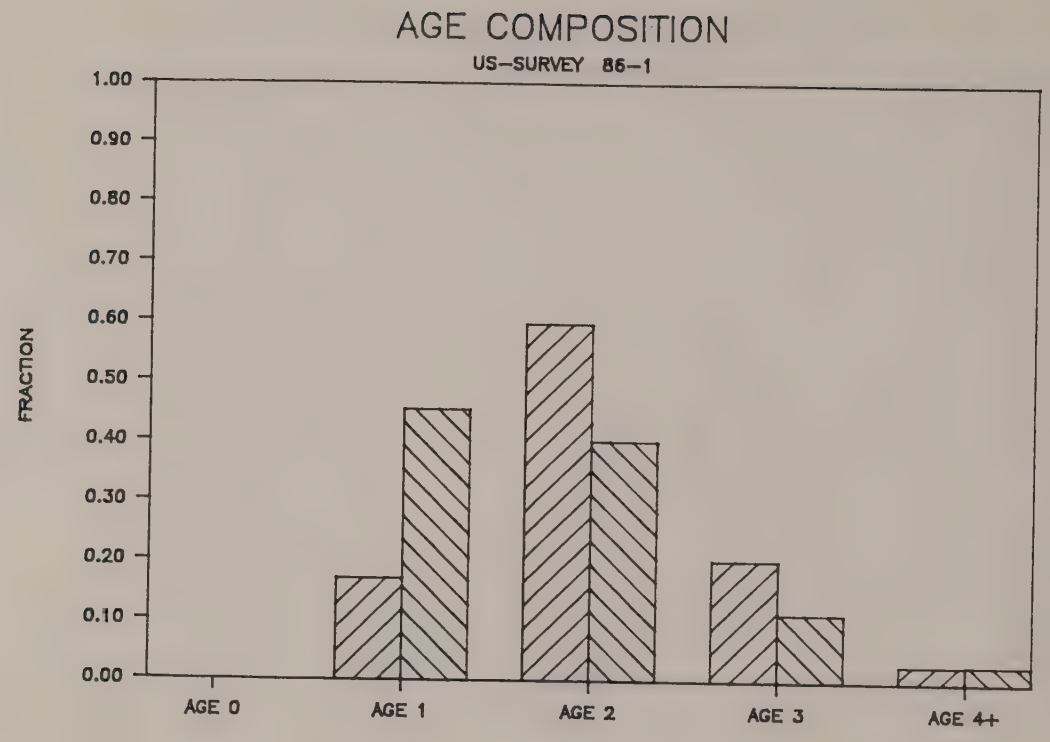
0.20
0.10
0.00
AGE 0
AGE 1
AGE 2
AGE 3
AGE 4+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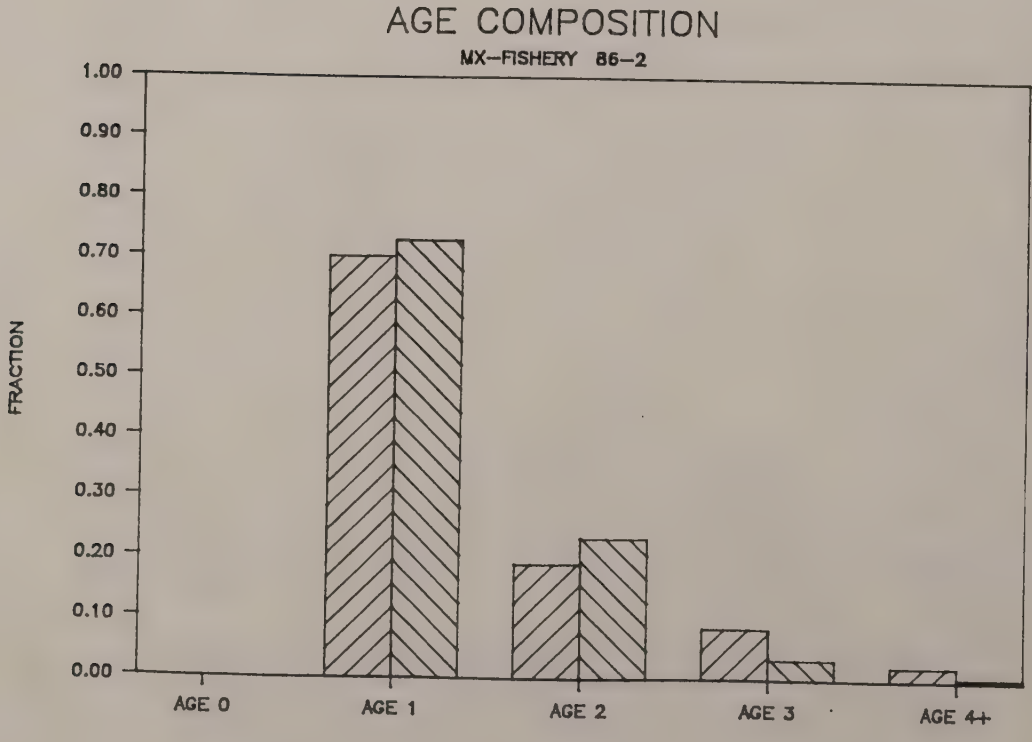
0.50
0.40
0.30
0.20
0.10
0.00
AGE 0
AGE 1
AGE 2
AGE 3
AGE 4+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0.80
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0.40
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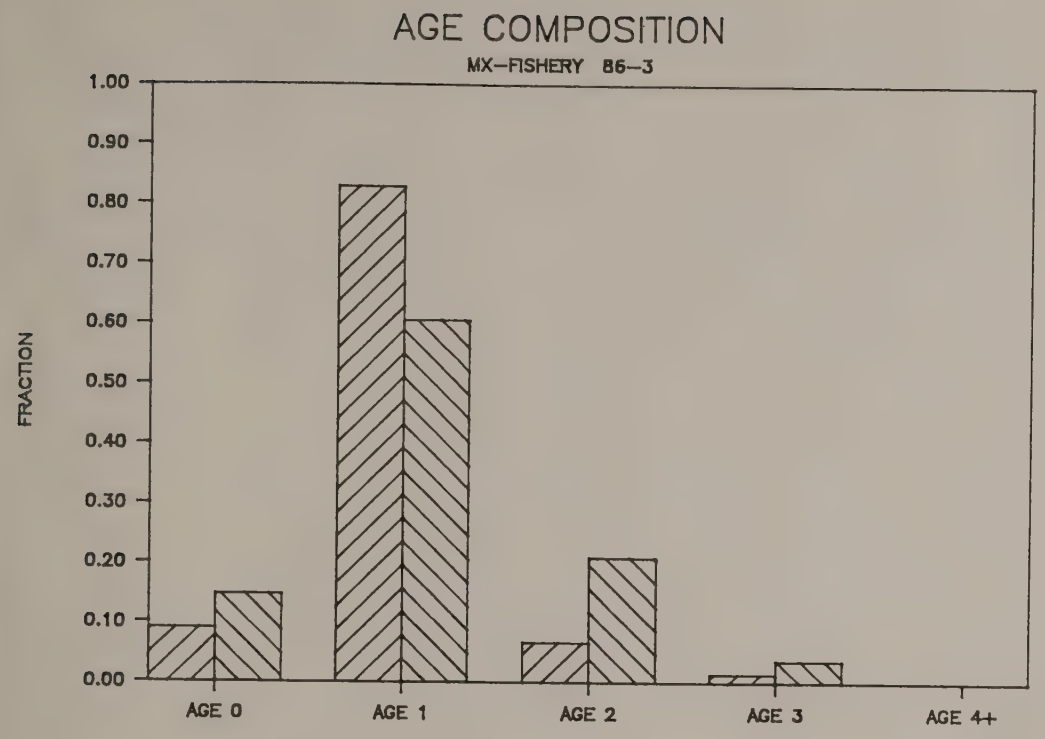
0.20
0.10
0.00
AGE 0
AGE 1
AGE 2
AGE 3
AGE 4+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0.80
0.70
0.60
0.50
0.40
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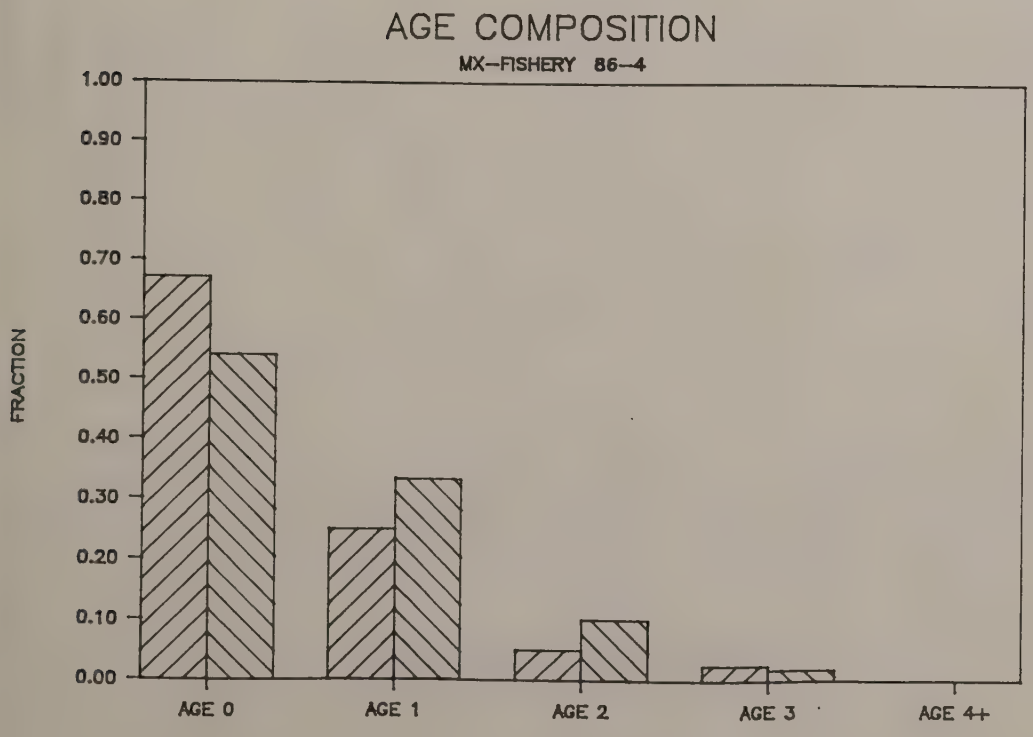
0.20
0.10
0.00
AGE 0
AGE 1
AGE 2
AGE 3
AGE 4+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MX-FISHERY 86-4
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0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
AGE 0
AGE 1
AGE 2
AGE 3
AGE 4+

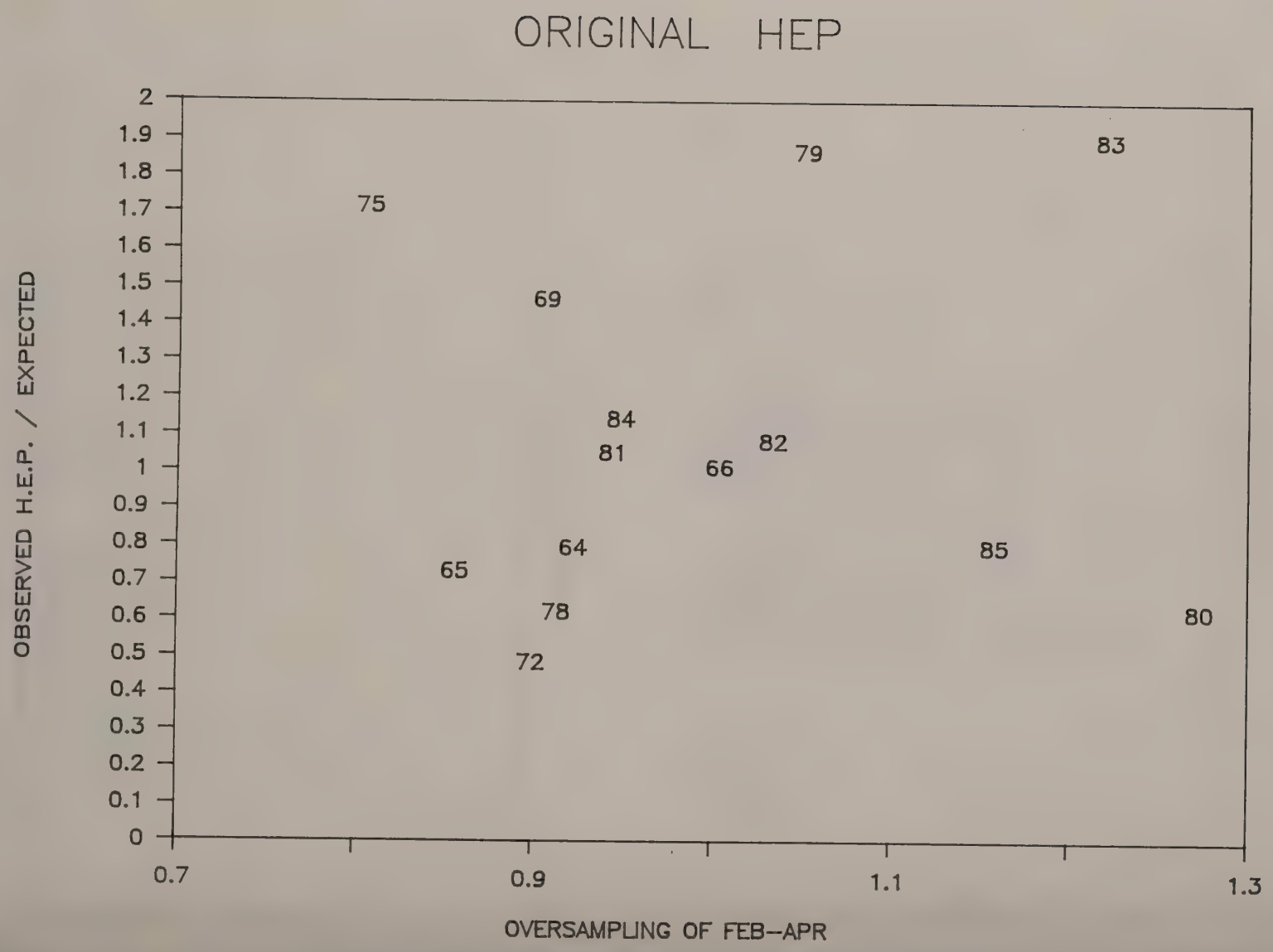
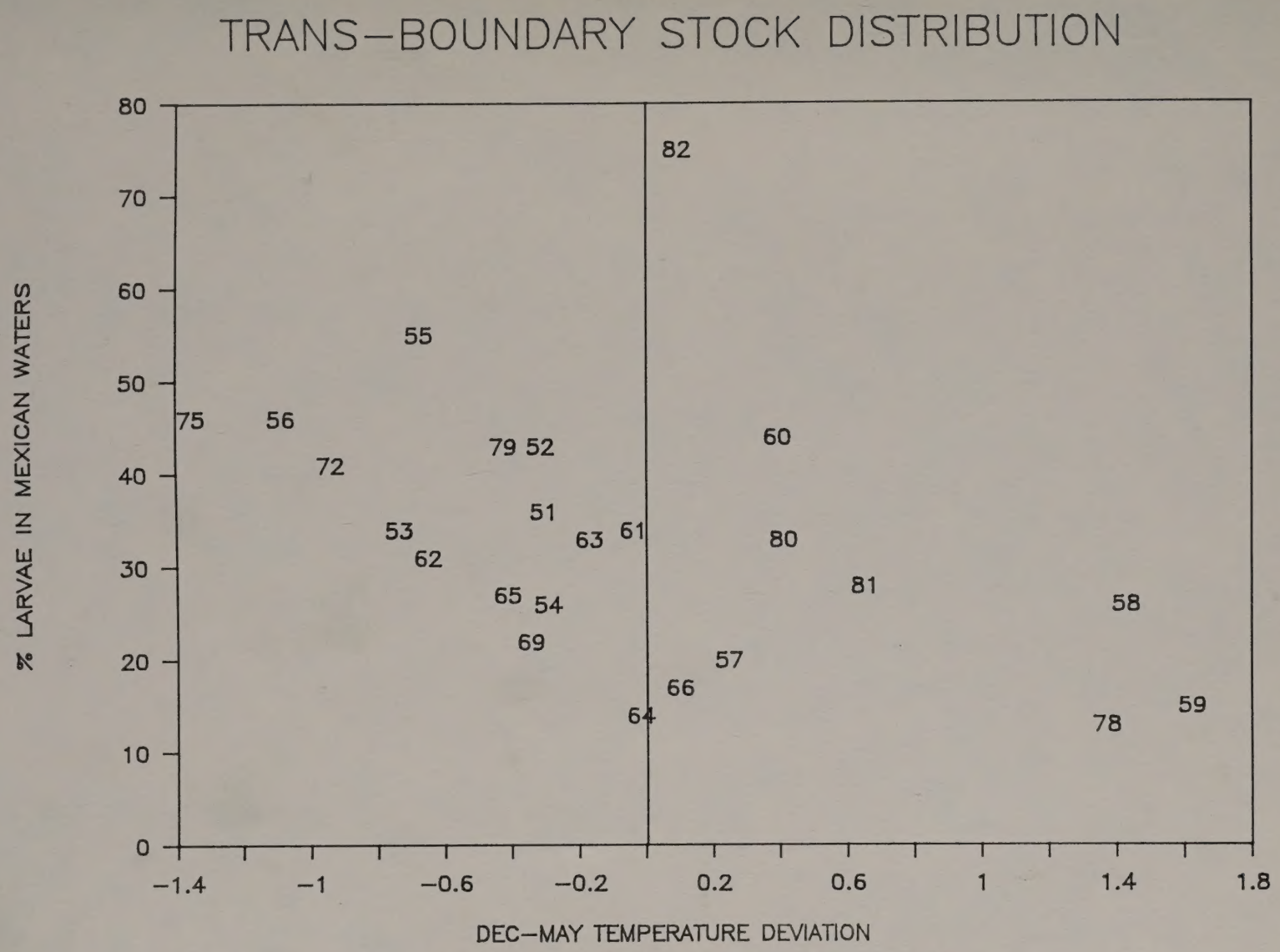


Figure 7. Relationship between deviations in the original HEP



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